Mimicking the Brain's Abilities

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Introduction

Von Neumann Architecture is a worldwide computing concept where data can be processed and stored into memory units. However, limitations come along with these advantages such as pattern recognition and data classification. Moreover, the excessive power requirement needed for these computers are a rising cause to global warming. Therefore, implementing neuromorphic architecture would prove to be more robust and stream-lined as these devices avoid such issues.

Learning Process

To begin the research process, learning the basic parts and its functions was essential. The largest part of the neuron is the soma and it contains the basic organelles of any cell while creating the neuronal proteins necessary for transmission. The neuron also has dendrites that receives information from other neurons in the form of neurotransmitters. In addition, the axon which extends from the cell's body serves to transmit the information. When these neurotransmitters bind to the receptors of another cell, an electrical impulse is activated as ion channels allow ions like Na+, Ca 2+, and Cl- to flow in and out the cell. Because the neuron has many dendrites, the cell's overall charge can be changed, activating an action potential.

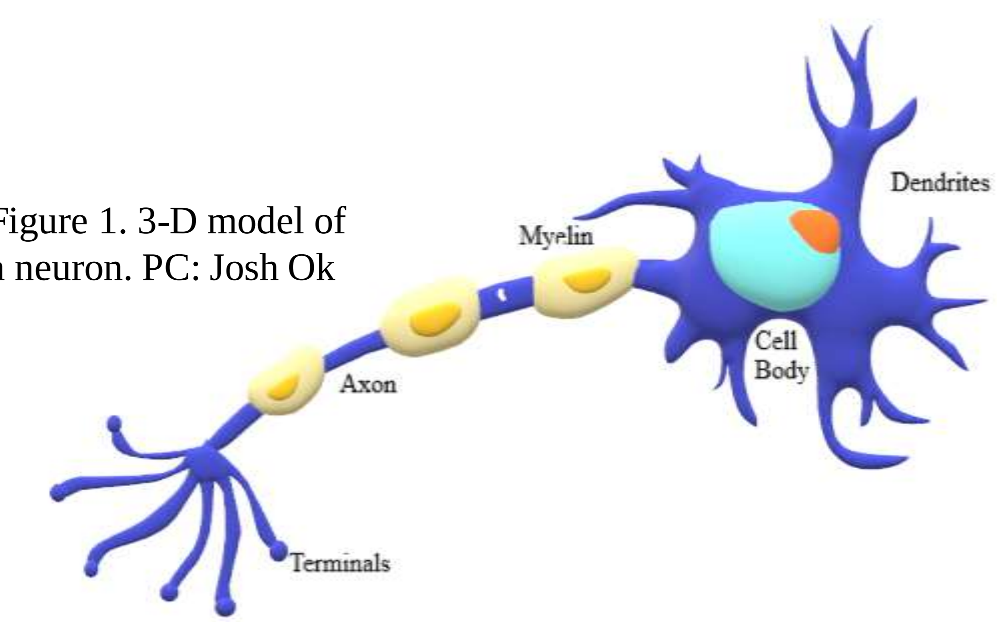

Figure 1. 3-D model of a neuron. PC: Josh Ok

Simulating Action Potentials with the Hodgkin-Huxley Model

--the graph in blue directed off of the Hodgkin Huxley model directly matches the span of an action potential:

- -neuron has excitatory postsynaptic potential when Na+ enters the membrane and reach a threshold of about -55 mV, ultimately triggering the opening of sodium ion channels
- -depolarization occurs as the sodium ions enters the axon, drastically changing the overall membrane potential to about 40 mV
- -potassium ion channels and the sodium-potassium pump opens and begins the repolarization process
- -the cell over-polarizes as the voltage reaches about -85 mV, hyperpolarizing the cell
- -both the sodium and potassium channels begin to close, entering the refractory period which is when the cell reaches the resting membrane potential (-65 mV)

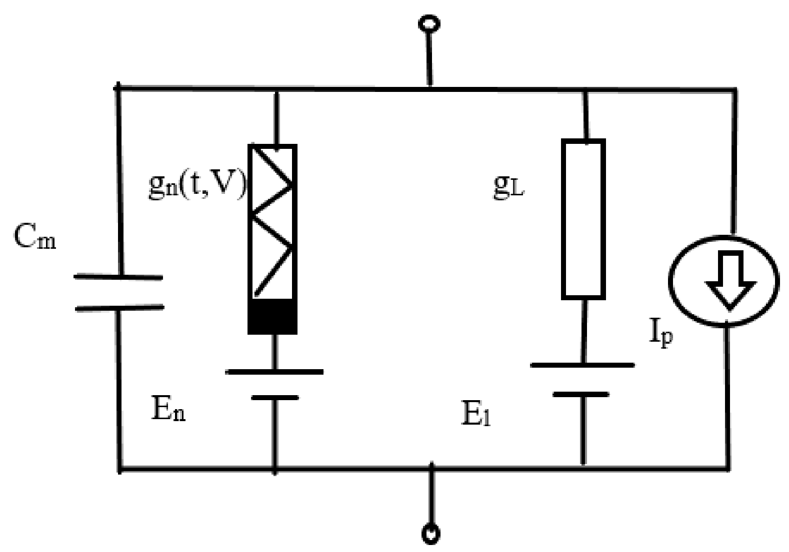

Figure 2. The basic diagram of the Hodgkin Huxley model displays an electrical representation of the biological neuron. PC: Josh Ok

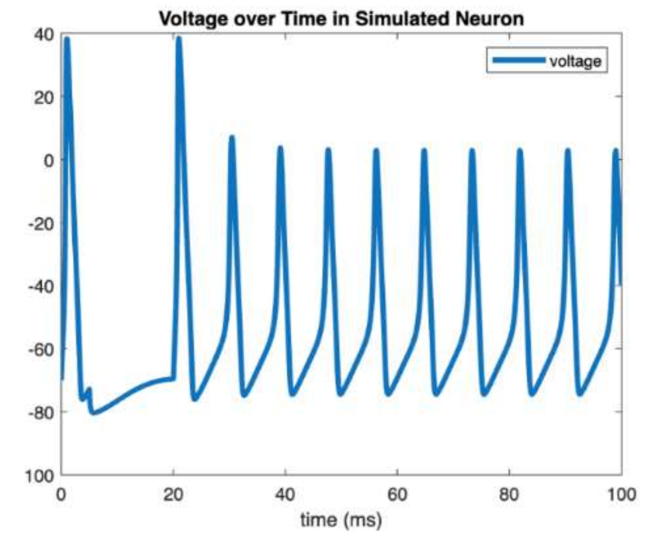

Figure 3. Graph: (Time vs Voltage) This graph was constructed off of the data provided from the Hodgkin Huxley model and indicates a similarity to the neuron's ability to produce action potentials. Adapted from "Introduction to Computation Modeling: Hodgkin Huxley Model" by Andrew Jahn

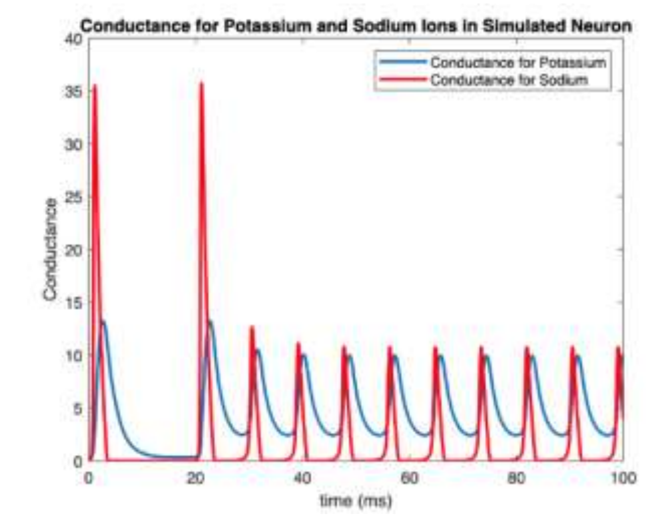

Figure 4.Graph (Time vs Conductance) The results demonstrate that sodium ion channels seem to be opening/closing quickly in comparison to the slower potassium ion channels, reinforcing the influx of sodium ions in the cell. Adapted from "Introduction to Computation Modeling: Hodgkin Huxley Model" by Andrew Jahn

Further Research

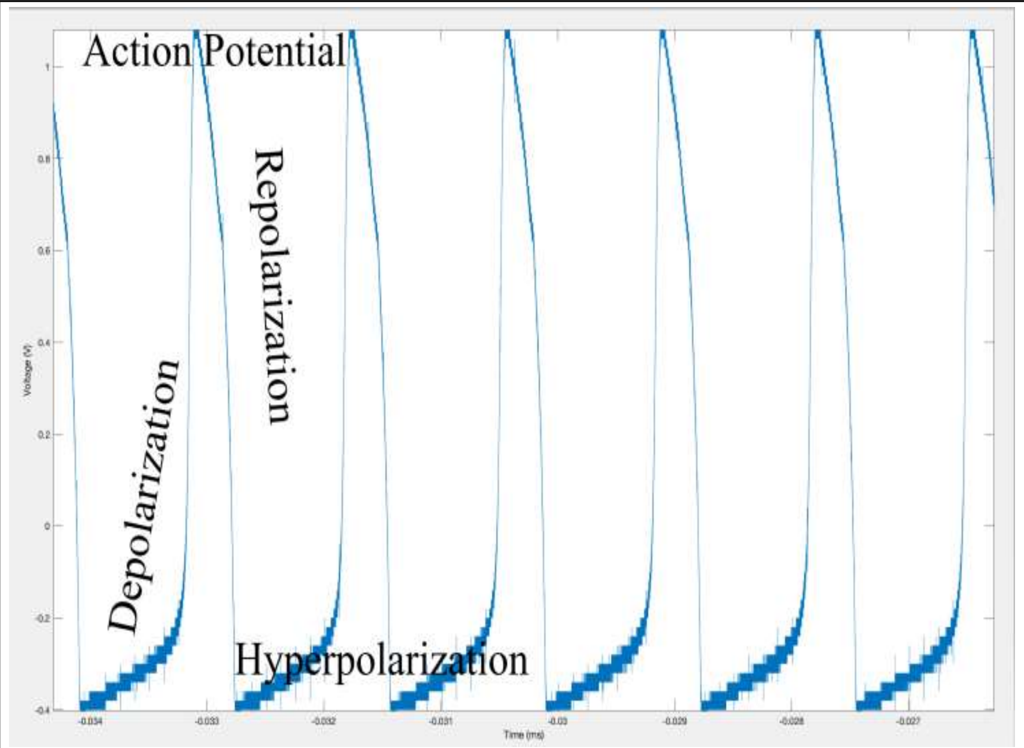

Figure 5. The given graph is constructed from Professor Kapadia's lab and displays the relationship between time (ms) and voltage (V) of oscillation data. The graph's pattern proves to follow the neuron's ability to produce action potential, but on a larger scale. Moreover, the frequency can be calculated by following the formula: 1/period. 1/(-0.03174-(-0.0330987))= 736 Hz. This inductance can be adjusted allowing the frequency to match that of biological neurons, further reinforcing the connection between biology and electrical devices. PC: Ragib Ahsan, Hyun Uk Chae.

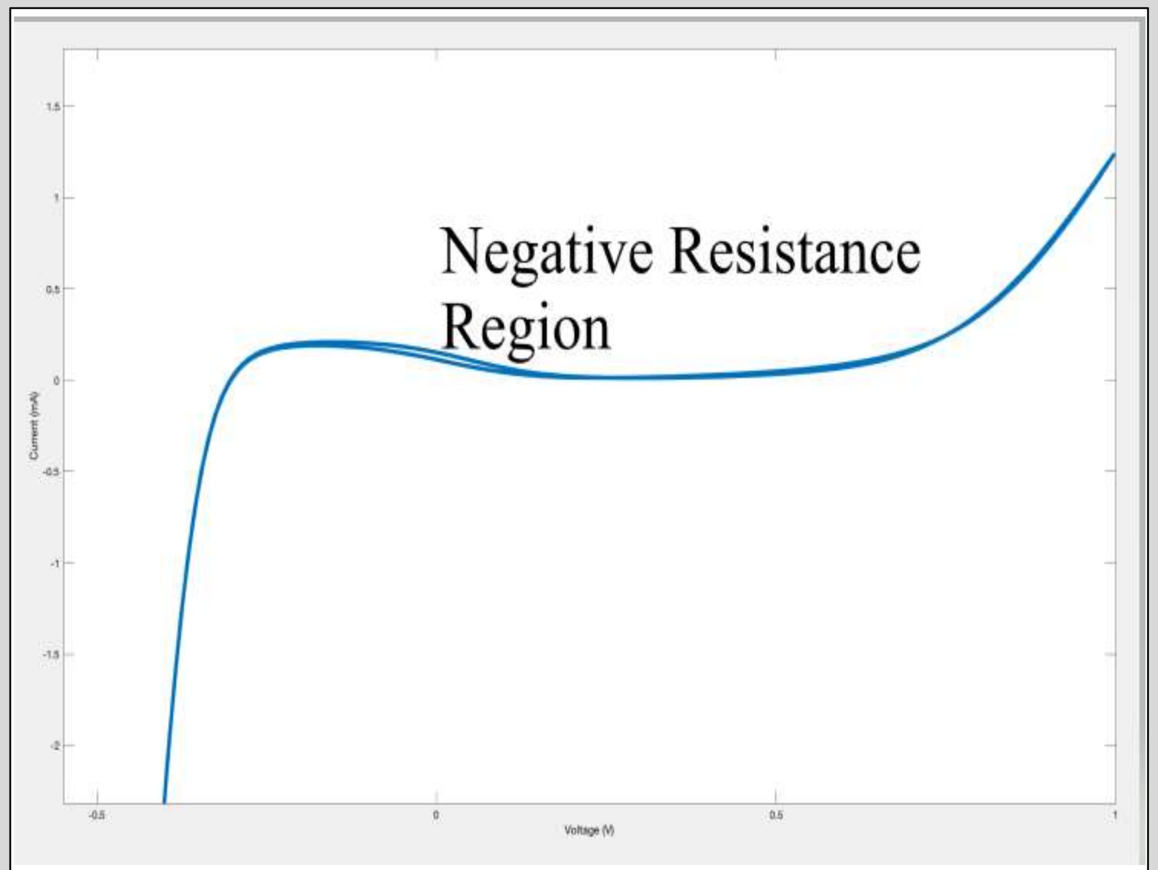

Figure 6. Also given by Professor Kapadia's lab, the graph above is a relationship between voltage and the current. As the voltage begins to increase, the current also increases until it reaches a certain point. Once the current reaches a specific point, it begins to decrease as the voltage continues to increase. That range representing a negative slope is known as the negative resistance region. This region indicates that within two points, an increase in voltage results in a decrease in current. If the voltage continues to increase, the current also follows the original trend of increasing, demonstrating a positive resistance region. PC: Ragib Ahsan, Hyun Uk Chae.

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